International Journal of Civil, Structural,
Environmental and Infrastructure Engineering
Research and Development (IJCSEIERD)
ISSN(P): 2249-6866; ISSN(E): 2249-7978
Vol. 5, Issue 5, Oct 2015, 89-98

FEASIBILITY STUDY OF GREY WATER FOR MIXING CEMENT AND MORTAR

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ABSTRACT

In India fresh and potable water is becoming scarce. Water is an integral part of all kinds of development. Construction industry is among the most water demanding industries. In order to cope up with the water demand of construction industry, the feasibility of grey water for mixing cement and mortar is assessed in this paper. In this study, two different equalized grey water samples were taken for bio-chemical analysis. Their qualities were compared with the quality requirements intended for mixing water. Both the grey water samples and Tap Water (TW) supplied by the municipal corporation were used for mixing cement and mortar. Standard consistency, initial and final setting times, soundness and compressive strengths of cement were determined by using both TW and GW for mixing. Results were used for comparison purpose. In the end, the elemental reports are derived which justifies the usage of grey water as mixing cement and mortar.

KEYWORDS: Cement, Grey Water, Mixing Water, Mortar, Tap Water

INTRODUCTION

Water is one of the most important elements in human life and construction. According to official statement of Government of India Ministry of Water Resources (2012), India has more than 17 % of the world's population, but has only 4% of world's renewable water resources. In India utilizable water availability is already under strain and there is possibility of expanding of water conflicts. As per all codes of concrete, the water used for mixing and curing should possibly be the potable water. Constructional activities play a major role in infrastructural development. Water has undisputed important place in civil construction and so far no alternative to water is available. It is seen that the use of potable water is further causing scarcity of water and that too in highly urbanized and populated areas, as these areas have the potential and need to expand. Almost all codes of concrete and mixing water indicate that constructional activities not essentially need fresh or potable water.

In this alarming situation, many Governments like Govt. of Queensland, institutions like WHO and NEERI and researchers has been focusing on the potential to use all types of wastewater. Duff A. Abrams (1924) studied and tested almost 68 different non-potable water samples including sea, alkali, mine, mineral and bog waters and highly polluted sewerage and industrial wastes on mortar and concrete specimens. Harold H. Steinour (1960) also tested various water samples for their suitability for mixing concrete. Joo-Hwa Tay et al.(1987) studied the use of reclaimed wastewater in

concrete. Franco Sandrolini (2000) investigated the effects of ready-mix concrete sludge water on concrete. Ooi Soon Lee et al. 2001, examined the effects of treated effluent on concrete. B. Chatveera et al. (2006), Marcia Silva et al (2010) studied the recycled sewage treatment plant water for the use in concrete. Mohd. Shekarchi et al. (2012) investigated effects of biologically treated domestic waste water in concrete. Almost all results of parametric study suggest the feasibility of using treated domestic waste water as mixing and/or curing water.

Construction industry is one of the most water demanding industry. It has flexibility to consume non-potable water for its need but then on acceptance attitude of people and health issues are the challenges to the complete utilization of wastewater. On this background, investigations on all possible uses of all types of waste water in construction industry, is the need of the hour. Present study has been conducted to investigate the influences of use of grey water for mixing cement and mortar.

Physico-Chemical Requirements of Water to be Used for Mixing

"Water fit for drinking is fit for all constructional activities like mixing cement, mortar, concrete and curing." That is potable water is always first choice of all codes of practices related with concrete. When sources other than potable water, water without any previous record or any questionable water are used, the water has to be qualified by tests. In case of doubt about the water available for constructional use, the suitability of water for making concrete shall be ascertained by the compressive strength and initial setting time specified in almost all concrete standards. Table 1 gives the Main criteria for the assessment of mixing water.

Table 1: Main Criteria Given By IS 456, EN 1008, ASTM C94, ASTM C1602 and AS 1379 (Cement Concrete & Aggregates Australia, 2007) For the Assessment of Mixing Water

Parameter	IS 456	BS EN 1008	ASTM C94/ASTM C 1602	AS 1379
Time of set	Initial set ≥ 30min and final set ≤ 10 h	Initial set ≥ 1 h and final set ≤ 12 h with both not differ by more than 25% from control.	From 1:00 early to 1:30 later than control	Initial set from 60 min earlier to 90 min later than control sample time.
Compressive strength	min 90 % of control at 28 days	min 90 % of control at 7& 28 days	min 90 % of control at 7 days	min 90 % of control at 7& 28 days

It has been observed that many chemicals in mixing water may create harm to concrete if present in excess amount. The impurities in mixing water harmful to concrete are compiled from various codes like ASTM C 1602/C 1602M-04, ASTM C94, BS EN 1008:2002, IS 456, AS1379-2007. These are Color, Odor, total solids, Chlorides, Sulphates, Acids, Alkali, phosphates, nitrates, lead, zinc, Oils and fats, Detergents, etc.

The critical limits presented by various concrete standards can be summarized as,

- As per EN 1008:2002 the color of mixing water shall be assessed as pale yellow or paler, there should be no smell or except the odour allowed for potable water. Any foam in the mixing water should disappear within 2 minutes. Concrete mixing water should have phosphate, lead, zinc and sugar concentration within the permissible limit of 100mg/lit. The nitrate concentration limit is 500mg/lit.
- **pH:** The pH of the water used for mixing should not be less than 4 as per EN-1008, 5 as per AS-1379 and 6 as per IS-456. According to Neville no significant effect observed within 6.0–8.0.

- **Total Solids:** Total Solids concentration should not exceed the maximum permissible limit of 50,000 mg/lit. as per ASTM C94 and ASTM C1602 and according to IS 456 it should be less than 2000mg/lit. & also less than 1% of total aggregates.
- **Oil and Grease:** The oil and grease concentration in the mixing water should not exceed the permissible limit of 50mg/lit. as per AS1379 or there should not be any visible traces of the same as per EN1008
- **Chlorides:** The chloride concentration as Cl should not exceed limit of 500mg/lit given by EN1008, ASTM C94, ASTM C1602 & IS 456.
- **Sulphate:** As per EN 1008, the sulfate concentration in the mixing water should not exceed the value of 2000mg/lit & according to ASTM C94 and ASTM C1602, 3000mg/lit. Prescribed values of to AS1379 & IS 456 are ≥500mg/lit and 400mg/lit respectively.
- **Total Alkalinity:** The total alkalinity in mixing water should be within the permissible limit of 1500mg/lit, 600mg/lit, 600mg/lit as per EN 1008, ASTM C94, ASTM C1602 respectively.
- No comment has been made on presence of micro-organisms by either of the standards. According to A.M. Neville (2005) concrete is generally resistant to microbiological attacks because its high pH does not encourage actions harmful to concrete.

Considering chances of health issues related to the safe handling of objectionable water must be considered. Biological treatment and pathogen reduction are used to ensure safety in handling reclaimed water. Disinfection methods can be adopted before use **(**Cement Concrete & Aggregates Australia, 2007).

EXPERIMENTAL PROGRAM

In this study, the grey water collection system was installed at two different locations. Grey water was first equalized for 24 hours and then samples were taken for bio-chemical analysis. Same grey water was used for mixing purpose.

The grey water samples (GW) from two different sources were used for mixing. For comparison municipal corporation supplied tap water (TW) was used to prepare control specimens. Standard consistency, initial and final setting times, soundness and compressive strengths of cement were determined by using both TW and GW for mixing. Two different mortar mixes H-1 and M-1 (SP 20, 1991) of two different consistencies were made by using grey water for mixing. Curing of these mortar cubes was done by the same grey water.

Test Procedures

- Equalized grey water samples were sampled and analyzed for potential pollutants of concrete by procedures given in different parts of IS3025.
- Standard consistency test was performed as per procedures given in IS4031part 4-1988.
- Initial and final setting time tests were carried out as per procedures in IS4031 part 5-1988.
- Soundness test was conducted in accordance with IS4031 part 3-1988 to ascertain the presence of free lime and magnesia by measuring the expansion of cement.

- Test of Compressive strength of cement was carried out according to IS4031 part 6-1988.
- Mortars were prepared according to SP 20 (1991) handbook on masonry design and construction--part 2.

MSaterials Used

- Cement: 53 Grade Ordinary Portland cement confirming to IS12269.
- Mixing water: Tap water (TW) confirming to IS10500 and grey water (GW) obtained from residential apartment and boy's hostel building was used in this study.
- Fine aggregates for compressive strength of cement: Standard sand obtained from Ennore, Tamil Nadu specified by IS650 was procured for compressive strength test of cement.
- Fine aggregates for Mortar: Locally available sand confirming to IS 383 was procured.

Various properties of the materials used are tabularised in Table 2.

Table 2: Properties of Materials Used in Experimentation

Cement	Ultratech OPC 53 GR.	Specific Gravity: 3.15Confirming To IS-12269
Fine Aggregates	Standard sand	Obtained from Ennore, Tamil Nadu specified by IS650
	Local Sand	Specific Gravity: 2.52, Fineness Modulus : 2.49, confirming to Zone-III grading as per IS 383Water Absorption: 0. 62% , Moisture content: Nil
Mixing water	Screened Grey water (GW)	Boys hostel, residential apartments
	Tap water (TW)	Confirming to IS-10500

Grey Water Collection

A set up as shown in Figure 1 was installed for the collection of grey water samples from boy's hostel of Government College of Engineering and also from residential apartments of State Government employees. Initially grey water was passed through two screens in first barrel to screen-out floating and suspended materials. In second barrel the water passed through 20 to 10mm coarse aggregates and then again through 10 to 4.75mm coarse aggregates for further filtration. Sludge valve is provided in every barrel for the periodic backwashing.

RESULTS AND DISCUSSIONS

Critical Elemental Analysis of Grey Water Used for Concrete Mixing

Color: As per EN 1008:2002 the color shall be assessed qualitatively as pale yellow or paler. The samples of grey water (GW1, GW2) used for mixing were light milky in color which is within the permissible limit.

Odour: According to EN-1008, no smell except the odour is allowed for the potable water along with a slight smell of cement and if the blast furnace slag is present in the water, a slight smell of hydrogen sulphide is also acceptable. Practically, no smell was noticed for both the grey water samples.

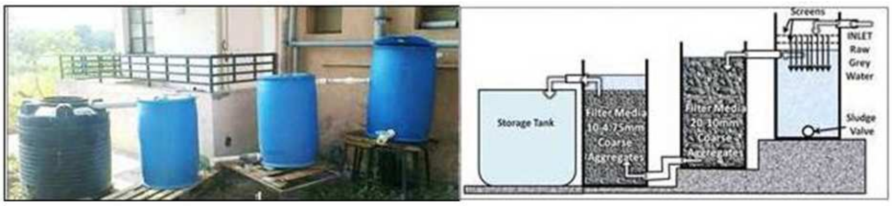

Figure 1: Schematic of Grey Water Screening Tank and Set up of Grey Water Screening Tank

PH: The pH of the water used for mixing should not be less than 4 as per EN-1008, 5 as per AS-1379 & 6 as per IS-456. According to Neville no significant effect observed within 6.0–8.0. The pH of the GW1 used for concrete mixing was 7.9 & that of GW2 was 7.8, hence are within the stipulated standards as mentioned above.

Detergent: According to EN-1008, any foam in the mixing water should disappear within 2 minutes and for both the samples of grey water used for concrete mixing the foam disappeared within a minute.

Total Solids: The Total Solids concentration was 170mg/lit. and 166mg/lit. for GW1 & GW2 resp. Total Solids concentration should not exceed the maximum permissible limit of 50,000 mg/lit. as per ASTM C94, it should be less than 2000mg/lit. as per IS 456 & also less than 1% of total aggregates. Therefore the used samples were under the mentioned specifications.

Oil and Grease: The oil and grease concentration in the mixing water should not exceed the permissible limit of 50mg/lit. as per AS1379 or there should not be any visible traces of the same as per EN1008. No visible traces have been observed in the both samples of grey water used for concrete mixing.

Chlorides: The chloride concentration as Cl for the GW1 & GW2 samples were 26mg/lit and 34mg/lit which are less than limit of 500mg/lit given by EN1008, ASTM C94 & IS 456.

Nitrate: The nitrate concentration of both samples was in the range of 0.071mg/lit. & 1.85 mg/lit. respectively, which is less than the limit of 500mg/lit. as per EN 1008.

Sulphate: As per EN1008 and ASTM C94 the sulfate concentration in the mixing water should not exceed the value of 2000mg/lit & 3000mg/lit respectively. It should also be less than 500mg/lit.& 400mg/lit according to AS1379 & IS 456 respectively. The sulphate concentration in GW1 and GW2 was found to be 1.4mg/lit. & 2.8 mg/lit resp. which is within the specified values.

Total Alkalinity: The total alkalinity in the grey water samples GW1 and GW2 was found as 104mg/lit. and 100 mg/lit. which is within the permissible limit of 1500mg/lit. and 600mg/lit. as per EN 1008 & ASTM C94 respectively.

Phosphates: GW1 & GW2 the samples used for concrete mixing had phosphate, lead and zinc concentration of 0.21, 0.17 & 0.9 and 1.2, 0.06 & 0.08 mg/lit respectively which is within the permissible limit of 100mg/lit as specified in EN 1008.

B.O.D. and C.O.D.: B.O.D. of the grey water samples, GW1 and GW2, used for concrete mixing were found to be 18 and 56 mg/lit., whereas C.O.D. values were 29 and 153mg/lit respectively. The C.O.D. to B.O.D ratios are 1.61 and 2.73. The COD/BOD ratio is a good indicator of greywater biodegradability. A COD/BOD ratio below 2–2.5 indicates easily degradable wastewater, While greywater is generally considered easily biodegradable (B. Jefferson et. al, 2004). Different studies indicate low greywater biodegradability with COD/BOD ratios of 2.9–3.6 (Peter Ridderstolpe, 2004).

This is attributed to the fact that biodegradability of greywater depends primarily on the type of synthetic surfactants used in detergents and on the amount of oil and fat present.

Total and Fecal Coliform: The total coliform concentration in the samples GW1 and GW2 of grey water used for concrete mixing was found to be 10MPN/100ml & 6.1 MPN/100ml whereas Fecal Coliform concentration was found to be 3.7MPN/100ml & 1.8MPN/100ml respectively. According to A.M. Neville (2005), concrete is generally resistant to microbiological attacks because its high pH does not encourage such actions.Nevertheless, under certain, fortunately rare, tropical conditions, some algae, fungi and bacteria can use atmospheric nitrogen to form nitric acid which attack concrete.

The proportion of pathogens in greywater is generally low. Pathogens are primarily added to wastewater with the faeces. The risk of infection is the function of thefaecal contamination of the water. As greywater does not contain faeces, it is normally regarded as rather harmless (Peter Ridderstolpe, 2004). Presence of fecal coliform indicate that greywater could create a health risk if it came into contact with humans Results of chemical analysis of Grey Water samples show that the presence of chemicals harmful to concrete are within the standard permissible limits mentioned in various codes. But due to presence of fecal coliforms in grey water it should be disinfected before use.

Results of Standard Consistency, Setting Time, Soundness and Compressive Strength of Cement

All these tests were carried out as per respective parts of IS: 4031. Three test samples each mixed by using TW, GW1 and GW2 were tested to determine standard consistency. Whereas six samples each were prepared and tested for determination of Setting time, soundness and compressive strength of cement. The relative values of test results are presented in Table 3.

Table 3: Relative Results of Standard Consistency, Setting Time, Soundness and Compressive Strength Tests of Cement

Mixing Water	Relative Result %				
	Standard Consistency	Set Time		Soundness	Compressive Strength, 28th Day
		Initial	Final		
TW	100	100	100	100	100
GW1	98.7	103.57	100.97	94.32	100.55
GW2	97.41	105.37	105.88	106.38	101.86

Results of standard consistency show that the amount of water required for Standard Consistency of cement is almost same in case of both TW and GW samples. In this case no significant difference in behaviour of TW and both samples of GW were noticed. With respect to the tap water, grey water mixes indicate slight increase in both initial and final setting time of cement. The increased values are also within the prescribed values given in IS 12269-1987.

For 53 grade cement, maximum expansion should be less than 10 mm when tested by the Le-Chatelier method (IS: 12269, 2013). Grey water mixed cement pastes show expansions almost same to that of the tap water cement paste. Both soundness test results are well within the prescribed limit given in IS 12269-1987.

It was found that grey water tends to increase the compressive strength of cement.

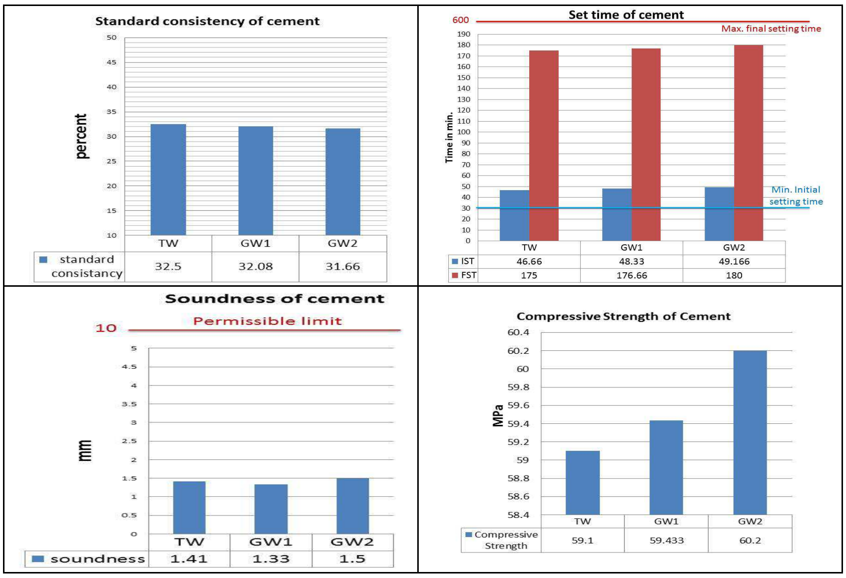

Figure 2: Comparison of Results of Standard Consistency, Setting Time, Soundness and Compressive Strength Tests of Cement by Using Tap and Grey Water for Mixing

Results shows that the compressive strength of cement mixed with Grey water is higher than that of tap water mixed cement. Figure 2 presents the comparison of results of standard consistency, Setting time, soundness and compressive strength tests of cement by using tap and grey water for mixing.

Results of Compressive Strengths of Mortar Cubes

Mortar cubes of 1:3 proportion i.e. H-1 mortar and 1:5 proportions i.e. M-1 mortar (SP 20, 1991) were casted using TW, GW1 and GW2. Two water cement ratios were used for different consistencies. Six cubes per mix were tested for compressive strength. Average 28th day strength test results are presented in table 4.

Tap water mortar samples and test samples of grey water mortar show no significant difference in compressive strength. However grey water mortars give little more strength than control or tap water mortar which can be seen in Figure. 3.

As per SP 20(S&T): 1991, handbook on masonry design and construction--part 2, the minimum compressive strength of H-1 mortar i.e. mortars of proportion 1:3 should be 10MPa and that of M-1 (1:5 mortars) should be 5 MPa. Three out of four mixes are satisfying the minimum strength requirement of SP20. Whereas average compressive strength of M-1 mixes, with 0.65 water cement ratio is less than the prescribed value. Out of eight, average compressive strength values of grey water mortar, two are less than control mix but the lowest value is 98.57%. The maximum % strength achieved by grey water mortars is 106.32%. All the values of the strength of grey water mortars satisfy the provisions given in different codes of concrete.

Table 4: Results of 28th Day Compressive Strengths of Cement Mortar Made by Potable and Grey Water

Mixing Water	Mortar Type	Proportion of Mix	W/C Ratio	Average 28th Day Strength M. Pa.	Relative Strength %
TW	H-1	1:3	0.5	14.233	100
		1:3	0.6	11.343	100
	M-1	1:5	0.55	6.66	100
		1:5	0.65	4.193	100

GW1	H-1	1:3	0.5	14.353	100.8
		1:3	0.6	11.553	101.85
	M-1	1:5	0.55	6.656	99.84
		1:5	0.65	4.333	103.33
GW2	H-1	1:3	0.5	14.76	103.7
		1:3	0.6	12.06	106.32
	M-1	1:5	0.55	6.93	104.05
		1:5	0.65	4.133	98.57

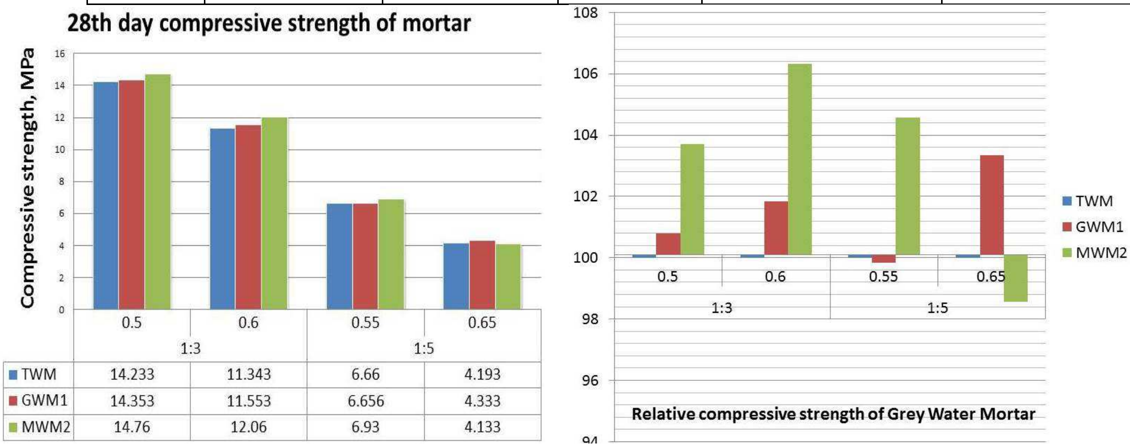

Figure 3: Comparison of 28th Day Compressive Strengths of Cement Mortar Made by Tap Water and Grey Water

CONCLUSIONS

- Scarcity of water points towards reuse of non-potable water for all purposes including construction.
- Grey water is relatively less polluted non potable source of water.
- Investigations by different researchers found that almost all non-potable waters can be used as mixing water.
- Analytical results of Grey water samples tested during this study also fulfil the chemical limits of mixing water.
- Other than screening, no special treatment is required to be given to grey water before its use for construction.
- Presence of faecal coliforms points out the need of disinfection before use for human safety.
- Regarding standard consistency of cement no significant difference in behaviour of TW and both samples of GW were noticed.
- With respect to the tap water, grey water mixes indicate slight increase in both initial and final setting time of cement.
- Soundness test results are well within the prescribed limit given in IS 12269-1987.
- Compressive strength of cement mixed with Grey water was higher than that of tap water mixed cement.
- Grey water mortars show little more compressive strength than control or tap water.
- Grey water can be used as mixing water.

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